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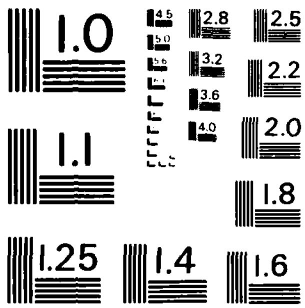

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ECONOMIC ANALYSIS MODEL
EVALUATION FOR TECHNOLOGY
MODERNIZATION PROGRAMS

ROBERT E. HAILS, JR., 1Lt, USAF

LSSR 92-83

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)
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Wright-Patterson Air Force Base, Ohio

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This research effort attempted to validate the economic analysis model contained in Chapter V of the Aeronautical Systems Division (ASD) Technology Modernization Guidebook published in July 1982. The ASD Model is used for determining the economic feasibility of potential capital investments. The researcher applied the ASD Model to the F-16 Tech Mod Programs and compared the ASD Model to actual savings data. Suggestions to improve and guidelines for applying the ASD Model were presented. Figure 3-1 illustrates the methodology employed by the author. Background literature reviews three existing Tech Mod Programs as well as several capital budgeting techniques used for investment decision making. Defense Department reports were also reviewed concerning the declining productivity growth within the defense industrial base. Implications of the research focus on the application of the ASD Model. The timing of the savings and purchase of the capital equipment were also important to ensuring accurate application of the ASD Model. Inclusion of "Lost Profit" as a variable in the ASD Model was recommended as well as better traceability of actual savings data to facilitate future validation studies.

ECONOMIC ANALYSIS MODEL EVALUATION FOR

TECHNOLOGY MODERNIZATION PROGRAMS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

By

Robert E. Hails, Jr., BS
First Lieutenant, USAF

September 1983

This thesis, written by

Lieutenant Robert E. Hails Jr.

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS MANAGEMENT

Date: 28 September 1983

Jack E. Atkins
COMMITTEE CHAIRMAN

Donald L. Brechtel
READER

To my wife, Laura.

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CHAPTER I

THE RESEARCH PROBLEM

Introduction

The decline in U.S. productivity growth from the early 1970's until present has precipitated a fervor of economic analysis. Economists have blamed the decline in productivity growth for partially causing the staggering inflation experienced in the late 1970's (19:81; 5:1). Figure 1-1 illustrates the recent trend in declining productivity growth by dividing the total output of the economy by total civilian employment (output per worker).

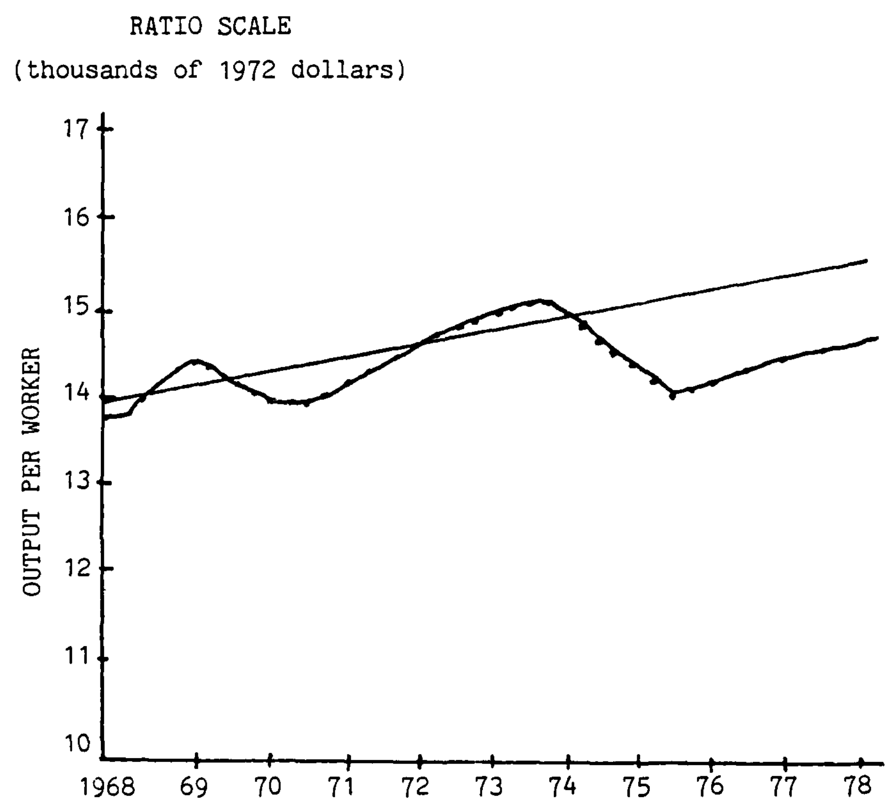

Fig. 1-1. PRODUCTIVITY IN THE U.S. (19:83)

Figure 1-1 reveals dramatic drop in output per worker in 1974.

> Since 1974 productivity seems to have fallen into a deep hole. From 1948 to 1973, output per worker rose by an average 2.4% a year. But from 1973 to 1976 this figure declined by an annual 0.5% and the decline has been wide spread [35:50].

The electronics industry is one example of the deteriorating manufacturing capabilities in the U.S.

> Edward N. Silcott, general manager of operations at the center (Westinghouse Defense and Electronic Systems Center's Materials Acquisition Center), said that in July, 1979, high technology electronics companies in the U.S. were assembling an average 12 acceptable printed circuit boards [12% yield] without rework other than solder touchup for every 100 kits of components that enter the process, while the Japanese had a composite yield of 85% [27:42].

Exactly why the U.S. productivity growth has declined during the past decade remains somewhat a mystery (19:82). Shifts in the composition of the labor force and the drastic increases in energy prices are two uncontrollable factors often cited in the literature (19:82; 35:50). Controllable factors include low investment both in research and development and capital equipment coupled with increased government regulations. Just how much each factor contributes to the decline in productivity growth is uncertain but the link between capital investment and productivity has been proven statistically significant by economists such as Edwin Mansfield and Edward Denison (19:82; 35:50). "Recent low levels of investment and

research and development have adversely affected productivity [19:88]."

Figure 1-2 depicts the relationship of capital investment to total output for five countries. The U.S. capital investment as a percentage of total output (GNP) is significantly lower than that of Japan, Canada, West Germany, and the United Kingdom. The subject of declining productivity growth has not gone unnoticed in Congress. General Alton D. Slay, former commander of Air Force

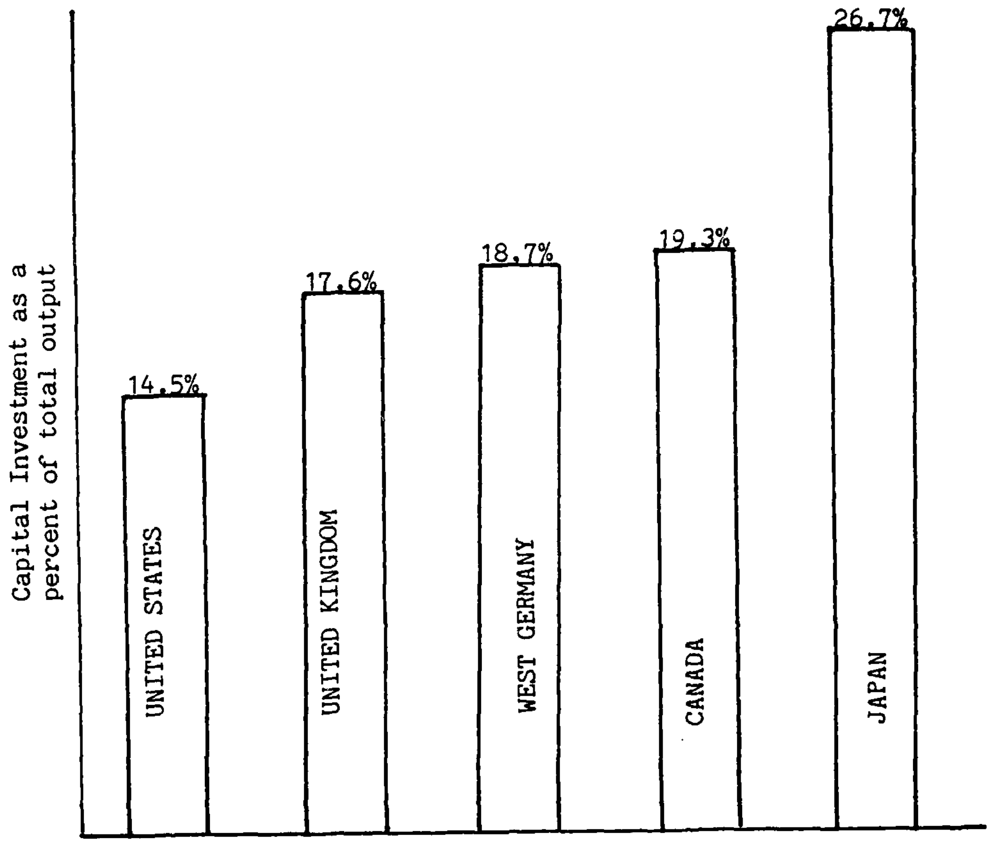

Fig. 1-2. CAPITAL INVESTMENT HERE AND ABROAD, 1970-77 (19:96)

Systems Command (AFSC), in his testimony before Congress, concluded that:

> Adequate investment in modern plant and equipment is key to increasing industrial productivity. The U.S. has fallen far behind other industrial countries in the level of capital investments in relation to GNP. Nations with higher levels of investment are also achieving higher annual increases in productivity in direct ratio to such levels of investment [31:V-16].

To address the declining U.S. productivity growth, the Committee on Armed Services, House of Representatives, chartered a panel on September 17, 198Ø, to study the U.S. defense industrial base. The panel held 17 days of hearings from 34 witnesses representing defense contractors, the General Accounting Office (GAO), Department of Defense (DOD), and the Congress. In providing the Defense Industrial Base Panel with testimony, General Slay illustrated (see Figure 1-3) how the aerospace industry

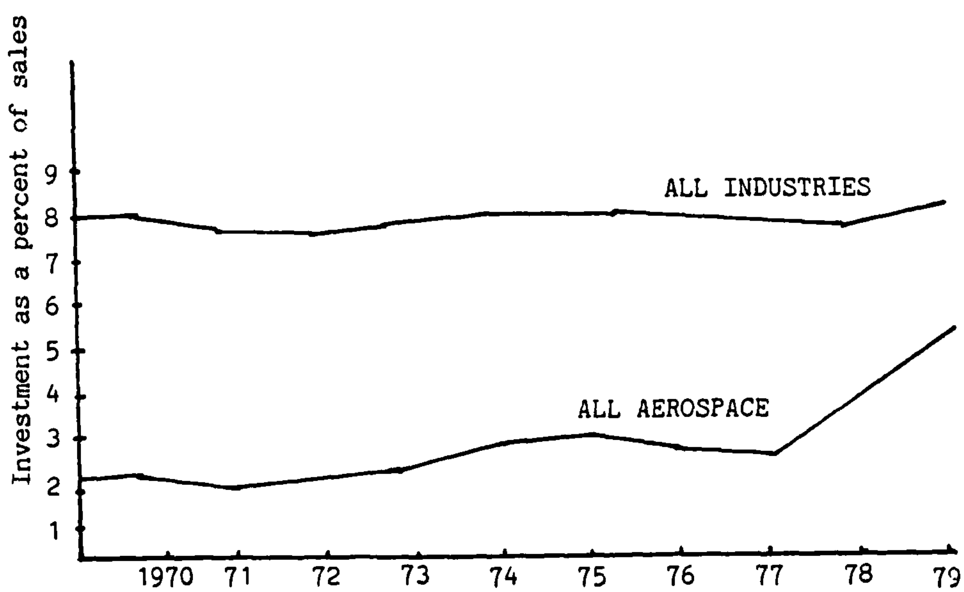

Fig. 1-3. U.S. INDUSTRIAL CAPITAL INVESTMENT (31:V-3)

(just one portion of the defense industry) has not kept pace with the rest of the U.S. industries in terms of capital investment. Investment is portrayed by year as a percentage of sales.

With strong testimony from individuals such as General Slay, the Defense Industrial Base Panel concluded that:

- the general condition of the defense industrial base has deteriorated and is in danger of further deterioration in the coming years, and

- current tax and profit policies appear to discourage capital investment in new technology, facilities and equipment that would increase productivity and improve the condition of the defense industrial base [33:1];

To combat this trend of declining productivity growth in the Department of Defense, considerable energy has been

> . . . directed at systematically bringing new and existing manufacturing technologies, and the capital investments needed to implement them, onto the production floor of the contractor's facility [1:ii].

This management direction originated from Congress through the Office of the Secretary of Defense (OSD) and was echoed down to the product divisions of Air Force Systems Command (AFSC). One specific program within AFSC designed to increase manufacturing productivity is Technology Modernization (Tech Mod).

> Technology Modernization embodies the wave of the future, not only in its attempt to stimulate investment by defense contractors in productivity growth but also

in its recognition of the more pervasive problem of overall U.S. industrial productivity [27:96].

What makes the Tech Mod program different from other productivity improvement programs is the contractual agreement between the government and contractor to share in both the investment in capital equipment and the savings resulting from increased productivity (1:3). After a particular capital investment has been selected for implementation, share ratios are negotiated between the government and contractor for expected future savings. The government will receive a portion of the actual savings through reduced costs for a particular weapon system. The Contract Administration Organization (CAO) assures compliance with share ratios throughout the life of the contractual agreement (1:10).

On July 28, 1982, the Aeronautical Systems Division (ASD) of AFSC published "A Guide to Technology Modernization and Contracting for Productivity [1:i]." The guide was intended ". . . to bring together all of our experience to date . . . [1:i]" on Tech Mod programs. The guide provides specific procedures to conduct a Tech Mod program within ASD. An economic analysis model titled "Economic Analysis and Cost/Benefit Assessment" is provided in Chapter V of the ASD Tech Mod Guide. The economic analysis model provides evaluation techniques for potential investments for a Tech Mod program. Chapter V is designed to

help the government decide on the economic feasibility of a particular Tech Mod program. The evaluation techniques include Internal Rate of Return (IRR), Discounted Payback Period (PBP), and Savings Investment Ratio (SIR) Chapter II of this thesis provides a more complete discussion of the evaluation techniques).

The ASD Tech Mod economic analysis model (hereafter referred to as the ASD model), however, has not been systematically applied to many Tech Mod programs. In fact, the Tech Mod program with Rockwell, El Segundo, California, on the B-1B program is the first time the ASD model has been used (18:82).

Problem Statement

The declining productivity growth in the aerospace industry, as a subset of all U.S. industries, has received considerable attention within the DOD and resulted in the establishment of the Technology Modernization (Tech Mod) program. In a guide recently published by the Aeronautical Systems Division (ASD), techniques are outlined to evaluate potential Tech Mod investments, but the economic analysis model in Chapter V of the ASD Tech Mod guide has been applied to only one program to date. Due to the resource requirement of Tech Mod programs, the means by which government funds are committed to candidate programs should be verified. Therefore, the economic analysis model in Chapter V of the ASD Tech Mod Guide needs to be

systematically evaluated to ensure the ASD model provides an accurate and logical basis for investing government funds.

Research Questions

To guide the research effort the following four research questions were developed. The first three research questions evaluated the ASD model with respect to the accuracy of the output using a decision rule. The fourth research question evaluates the ASD model with respect to variables used.

1. What is a good predictor of return on investment for a Technology Modernization program?

2. Was the capital budgeting model used by the Systems Program Offices (SPO's) within ASD to evaluate potential Tech Mod investments a good predictor of actual return on investment?

3. Is the ASD model a better predictor than the SPO estimate of the actual return on investment?

4. If the ASD model is not a better predictor than the SPO model what variables in the ASD model have the greatest impact on internal rate of return and what possible improvements could be made to the ASD model?

Scope of Research

Tech Mod programs have been initiated throughout the Department of Defense (DOD) as a result of Congressional investigation mentioned above. As a subset of the

DOD, Air Force Systems Command (AFSC) has approximately thirteen Tech Mod programs, the majority of which are managed by Aeronautical Systems Division (ASD) a product division within AFSC. The ASD Tech Mod Guide dictates economic analysis techniques for ASD managed programs only. Therefore, to evaluate the ASD model only existing Tech Mod programs within ASD were studied in this research effort.

Assumptions Made

1. The data provided to the researcher for the estimated cash flows (i.e., savings) resulting from the Tech Mod programs were assumed accurate.

2. Assumptions made by either the SPO economic analysis model or the ASD model were also utilized by the researcher.

3. Data omitted from both the SPO economic analysis and the actual savings for the Tech Mod programs did not impact the comparisons made by the researcher.

Limitations of Research

1. The primary focus in the author's research project was the quantitative aspects of the cost/benefit analysis performed for a Tech Mod program. Political and social ramifications of the Tech Mod program were not considered in this study.

2. The sample spaces used to answer the four research questions were chosen based on data accessibility

and acknowledged expertise in the area of Technology Modernization.

Summary

Technology Modernization (Tech Mod) is a relatively new concept aimed at increasing the productivity of the U.S. defense industrial base. As a major buying division within the Air Force Systems Command, ASD presently manages several Tech Mod programs. A recent publication of ASD (the ASD Tech Mod Guide) includes an economic analysis model that yields untested and unverified predictions of return on investment. This research project examined one Tech Mod program and 'expost-facto' utilized the ASD model to evaluate the accuracy of the ASD model. The following chapter reviews the literature on Tech Mod and the capital budgeting techniques used in the ASD model.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter provides operational definitions for the Technology Modernization program and capital budgeting techniques used in Chapter V of the ASD Tech Mod Guide. Assumptions, variables, and implementation procedures are then outlined for three Tech Mod programs in ASD as well as the assumptions, variables, and implementation procedures used in the ASD Tech Mod Guide. Finally, a survey of the literature resulting from the Congressional review of the declining productivity trend in the U.S. defense industrial base is presented.

The Technology Modernization Program

The Technology Modernization (Tech Mod) concept was first implemented by the F-16 System Program Office (SPO) during the mid 1970's (1:3; 12:30). The close cooperation between the F-16 SPO Director, Major General James Abrahamson, and the prime contractor, General Dynamics, Fort Worth Division, enabled the development of ". . . a strategic plan for technology/facility improvement [1:3]." As published in an Air Force Systems Command (AFSC) study,

> The potential F-16 manufacturing cost savings is in excess of $370 million over 1388 aircraft. The Air Force share of the savings is expected to be in excess of $220M [12:30].

With the widely published success for the F-16 program, other system acquisition programs within AFSC initiated Tech Mod efforts. Such programs include the Tech Mod effort with Lockheed-Georgia Company Division, Marietta, Georgia (GLAC); and the B-1B Tech Mod program with Rockwell International, El Segundo, California.

Tech Mod Program Phases

There are three phases to a Tech Mod program. The first phase is the Analysis and Conceptual Design phase during which the entire factory is studied to identify methodologies to improve the manufacturing process.

> It includes an analysis of advanced manufacturing technologies, contemporary equipment, quality assurance, production control, and management information systems [12:33].

Analytical tools such as Integrated Computer Aided Manufacturing/Definition (IDEF)[1] are used for the "top-down" factory analysis. The analytical tools were developed under a similar productivity improvement program called Integrated Computer Aided Manufacturing (ICAM). Funding for the Phase I study effort is provided by the government or by both the contractor and government. The

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[1]For an indepth discussion of IDEF methodologies see Ross, D. T., et al. "Integrated Computer-Aided Manufacturing (ICAM) Architecture Part II. Volume IV - Functional Modeling (IDEFO), "unpublished technical report, unnumbered, Materials Laboratory, Air Force Systems Command, Wright-Patterson AFB, OH. ADA B062457.

product of the Phase I effort provides the basis for the business deal. The business deal of a Tech Mod program is what distinguishes Tech Mod from other productivity improvement programs. The business deal establishes contractual funding responsibility between the government and contractor resulting in shared savings for the remainder of the Tech Mod program (1:2).

The second phase of the Tech Mod program is the Detailed Factory Modernization Design phase. During the second phase, actual development and detailed analysis of selected technologies take place.

> Phase II also identifies implementation plans, specifies hardware/software operational requirements and validates specific applications through method demonstrations [1:1].

Responsibility for funding the second phase is normally shared by both the government and contractor.

The third and final phase of a Tech Mod program is the actual implementation of factory modernization. The third phase includes contractor purchase and installation of investment candidates that demonstrated the highest potential payback during Phase II.

> Advanced management information systems, production planning tools, and the cost tracking and performance assessment system should also be ready for implementation [12:34].

A Tech Mod program can be initiated at any time during a major weapon system's life cycle. Figure 2-1 illustrates the three phases of a Tech Mod program. It is

most desirable to invest in capital equipment prior to production to amortize the investment over larger production quantities.

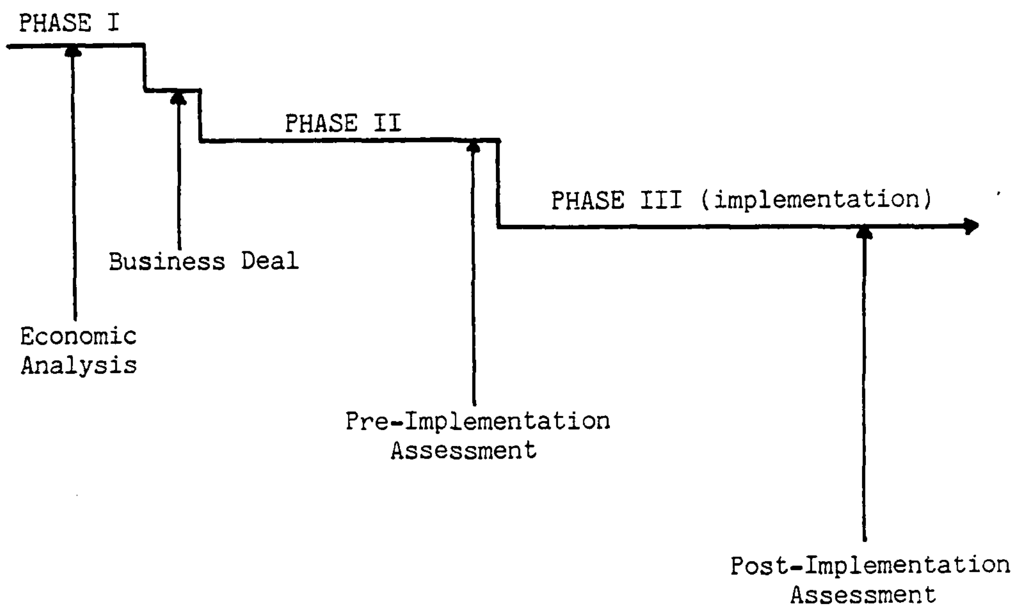

Fig. 2-1. TECH MOD PROGRAM PHASES (1:43)

Tech Mod Criteria

Criteria for prioritizing Tech Mod candidates are varied but include (1:31):

1. Reduced cost,
2. Return on investment,
3. Leadtime reduction,
4. Increased flexibility/surge capability/military worth,
5. Increased quality,

6. Improved technological advancement,
7. Technology transfer opportunities,
8. Reduced critical materials needs,
9. Multi-service potential,
10. Improved private sector capital investment commitment, and
11. Increased competition.

Each product division within Air Force Systems Command (AFSC) has a designated focal point for Tech Mod. "The Deputy for Contracting and Manufacturing should be responsible for nominating, planning, and budgeting Tech Mod programs [12:31]." The Tech Mod focal point at each AFSC buying division coordinates efforts with the SPOs on the Tech Mod programs. Technical assistance in evaluating potential programs is obtained from the Materials Laboratory, Air Force Wright Aeronautical Laboratories (AFWAL), Wright-Patterson AFB, Ohio.

> Coordinating the above contractual, manufacturing, and technical expertise is the responsibility of the SPO Director's personal involvement [12:31].

<u>Capital Budgeting Techniques for the Investment Decision</u>

Attempts to estimate certain costs and benefits resulting from alternative courses of management action have been used within the Defense Department for several decades.

> The basic idea is not new: individuals have presumably been weighing the pros and cons of

> alternative actions ever since man appeared on earth [23:467].

Formal cost-benefit analysis was originally applied to natural resources planning projects (8:168). Applications then spread to many federal agencies, including the Department of Defense under the nomenclature of systems analysis (8:168; 24:175; 32:212; 29:1). Alan C. Enthoven, then Assistant Secretary of Defense for Systems Analysis, stated before Congress on May 17, 1966 that, "Systems Analysis is a regular working contributor to the annual Defense decision-making cycle [8:159]." That same year, Robert S. McNamara, then Secretary of Defense, used systems analysis to rank various manned bomber programs (B-52, B-58, FB-111) and various air launched missile programs (SRAM, AMSA, HOUND DOG) (24:175).

> The profitability of an investment decision depends on two vital factors: (a) future net increases in cash inflows or net savings in cash outflows, and (b) required investment [14:404].

The ASD economic analysis model uses three capital budgeting techniques to rank potential Tech Mod investments; Internal Rate of Return (IRR), Discounted Payback Period (PBP), and Savings Investment Ratio (SIR). The following discussion of capital budgeting techniques is provided to familiarize the reader with the basic techniques set forth in the ASD model. Discounting cash flow and accrual accounting methods will be reviewed. Various assumptions pertaining to the discount rate, inflation, taxes and

depreciation will be discussed followed by methods used to deal with risk (uncertainty).

"Because the discounted cash-flow model explicitly and routinely weighs the time value of money, it is usually the best model to use for long-range decisions [14:406]." The underlying concept of any discounted cash-flow (DCF) model is that a dollar today is worth more than a dollar at some time in the future. By discounting future cash flows (or savings) downward to account for the time value of money, comparative analysis becomes possible between alternatives (28:138). There are two main DCF variations: (1) Internal Rate of Return (IRR) and (2) Net Present Value Index (PVI) or Savings Investment Ratio (SIR). The PVI method discounts future cash flows (or savings) back to the present by some predetermined discount rate. By dividing the total discounted cash flows by the initial investment a present value index or savings investment ratio can be developed. Conversely, the IRR method finds the discount rate at which the PVI or SIR is equal to one. When the PVI or SIR is equal to one, cash benefits exactly equal the investment. The discount rate calculated using the IRR method is often referred to as the "hurdle rate" (14:412).

The Payback Period (PBP) is an accrual accounting method of evaluating alternative investments. The payback period is calculated by dividing the initial investment by

the annual cash flow which yields the number of years required to recoup the investment. If annual cash flows are uneven, an average annual cash flow is calculated. The PBP method ignores profitability and the timing of cash flows within and after the payback period. Despite serious theoretical drawbacks, the PBP method is still commonly used in business (26:674).

Peculiarities of the two DCF techniques deserve mention before the techniques are used to rank alternative investments. The IRR method requires cumbersome trial and error calculations which become numerous when different annual or initial investment cash flows are involved. Additionally, the IRR is not an appropriate method for comparing alternatives with unequal lives (28:319). Finally, both DCF methods assume reinvestment equal to the indicated rate of return. The above nuances can lead to different rankings from the two DCF techniques. The conditions under which different rankings can occur are as follows:

> 1. The cost of one project is larger than that of the other; or
>
> 2. The timing of the projects' cash flow differs. For example, the cash flows of one project may increase over time, while those of the other may decrease; or the projects may have different expected lives [34:296].

The impact of the discount rate on the NPV method and resulting SIR cannot be understated. The SIR reflects

an upward bias as the discount rate moves downward. The relationship between rate and ratio often leads to different rankings for the alternatives. There have been many arguments concerning which rate to use on government projects (3:292). William Baumol, a Professor of Economics, at Princeton University, epitomizes a school of thought regarding the discount rate as an opportunity cost of alternatives foregone (4:513). Alternatively, some feel that the government (in particular DOD) does not have the opportunity to invest elsewhere and, therefore, should use some lower rate (for example government bonds). Regardless of the rate chosen, when ranking alternative investments, the same discount rate must be used.

Inflation can affect future cash flows and should be addressed when calculating an investment's NPV or SIR. If estimates of future cash flows include predicted inflation, then that same predicted inflation must be included in the discount rate (3:294). Similarly, if the estimated future cash flows are in current year dollars, then the discount rate should be cleansed of its inflation estimate.

The DCF techniques consider the initial investment as a lump sum at time zero the (time the investment is purchased). Depreciation then is a non cash expense which should not be deducted from estimates of future cash flows. However, the effect that depreciation has on income

taxes paid should indeed be a portion of the estimates of future cash flows. This effect can vary as depreciation schedules change. "The general rule in shrewd income-tax planning is: When there is a legal choice, take the deduction sooner than later [14:439]."

The DCF techniques assume future cash flows are known with certainty. Because this is seldom the case, there exists much literature on evaluating alternatives under uncertain conditions. Operations research literature focuses on techniques such as linear programming, probability trees, and simulation. However, sensitivity analysis can be performed on the SIR in relation to various discount rates. Such analysis can provide management with information regarding changes in estimated cash flows (26:725).

The above discussion of capital budgeting techniques used to evaluate alternative investments should assist the reader in properly applying those techniques used in the ASD model. A complete review of capital budgeting techniques can be found in any managerial accounting text such as Wayne Morse's book (26:5).

Applications of the Technology Modernization Concept

This section of the literature review highlights key assumptions, variables, and implementation guidelines for three Tech Mod programs currently managed at ASD.

Additionally, a review of the ASD model is included using the same format.

F-16 Tech Mod Program Overview

Management responsibility for the F-16 Tech Mod program with General Dynamics in Fort Worth, Texas is currently located within the F-16 System Program Office (SPO) at Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio. Specifically, F-16 SPO Directorate of Manufacturing personnel conduct the various management tasks for the F-16 Tech Mod program which included the original economic analysis of potential capital investments (9:83). The Internal Rate of Return (IRR) was the capital budgeting technique used by F-16 SPO personnel to evaluate alternative capital investments (9:13).

As the F-16 Tech Mod program has matured since the mid 1970's, many Tech Mod projects have been funded and implemented. Manufacturing technologies, such as in-process inspection systems and fabrication improvements high speed drill presses, are just two examples of the many projects implemented under the F-16 Tech Mod program. The F-16 Tech Mod program is currently in Phase III of the Tech Mod life cycle where full scale implementation of selected technologies takes place. The F-16 SPO had the Tech Mod business deal with General Dynamics written into the FY80 F-16 Procurement (F33657-78-C-0669) contract (10:i). The production contract normally is the vehicle

for government funding of various Tech Mod projects to achieve projected savings. F-16 Tech Mod projects are grouped together by fiscal year in which the projects are scheduled for implementation. These Tech Mod project groups are referred to as Capital Approprition Request (CAR) Packages. The F-16 SPO funds the approved CAR Packages by providing incentives to General Dynamics. Funding of the approved capital investments takes place after the F-16 SPO personnel conduct an economic analysis of each investment. By taking the estimated savings from a particular investment and adding the variables described below, the F-16 SPO personnel calculate the amount of incentive (funding) necessary to award General Dynamics as a "negotiable" internal rate of return. The F-16 SPO personnel estimate an IRR of 20 to 30 percent is required for General Dynamics to invest in any Tech Mod project. Typically, the F-16 SPO will develop several incentive amounts resulting in a contractor IRR between 20 and 30 percent. The incentive amounts are negotiatied, not the various IRR percentages. Incentives are then awarded based on a factor of compliance/achievement of estimated savings.

F-16 Tech Mod Program Assumptions

The assumptions used in the F-16 Tech Mod Program are as follows (21:12):

1. Assumptions associated with the IRR capital budgeting technique were used (i.e., investment outlays occur at the beginning of each year while savings are realized at the end of each year).

2. Investment depreciation costs are completely recoverable.

3. An average DOD profit level of 10% was assumed.

4. A "reasonable" program duration was assumed for future cost avoidances.

5. A corporate tax rate of 46% was assumed.

6. An investment tax credit of 10% was assumed.

7. All depreciation schedules were in accordance with Cost Accounting Standards Board (CASB) and Internal Revenue Service (IRS) regulations.

8. Estimated savings were based on 1388 total aircraft and then year labor and inflation rates.

<u>F-16 Tech Mod Program Variables</u>

The variables included in the F-16 Tech Mod program are listed below (21:13):

1. The initial investment required by General Dynamics.

2. Increased contractor share of savings - the incentive paid by the government to General Dynamics to invest.

3. Added profit on depreciation - because depreciation is an allowable cost on government contracts, General Dynamics will receive additional profit for each investment depreciated.

4. Lost profit - because profit is calculated as a percent of total cost, savings resulting from investments will lower contractor profit.

5. Cost of money - The Cost Accounting Standard Board (CAS 414) allows a percent of the cost of investing in facility improvement to be used in contractor profit calculations.

6. Contractor share of savings - the percent of savings the contractor receives through the contract.

7. Depreciation - source of instant collateral to the contractor per CASB or IRS regulations.

8. Investment tax credit - 10% of initial investment.

By summing the variables above, an after tax cash flow can be calculated for each year. The cash flow is then used in conjunction with the initial investment to calculate an internal rate of return.

F-16 Tech Mod Program Implementation

The F-16 SPO personnel use the calculated IRR only for support in negotiations (9:83). Actual incentive dollar figures are negotiated. The F-16 SPO personnel considered a 20 to 30 percent IRR is necessary for General Dynamics to invest in any Tech Mod project. Government IRRs vary according to technical, political, and social considerations but are never less than ten percent. Sensitivity analysis is also performed by SPO personnel to evaluate various incentive payment schedules. Specifically, it may be more advantageous for the government to provide fifty percent of the incentive payment required the first year and fifty percent the second year than to provide all necessary funding up front.

GLAC Tech Mod Program Overview

Management responsibility for the Tech Mod program with Lockheed-Georgia Company Division (GLAC) in Marietta, Georgia is currently located within the Airlift System Program Office (SPO) at Aeronautical Systems Division

(ASD), Wright-Patterson AFB, Ohio. Specifically, Airlift SPO Directorate of Contracts personnel conduct the various management tasks of the GLAC Tech Mod program to include economic analysis of potential capital investments (11:83). The Internal Rate of Return (IRR) is the capital budgeting technique used by the SPO personnel to evaluate alternative capital investments.

Initially a total of 12 Tech Mod projects were approved and funded under contract number F33657-81-C-0556 (2:21). Computer aided setup (CASP), voice data entry system (VDES), and brush deburring (BD) are examples of the 12 projects authorized. The GLAC Tech Mod program is currently in Phase III of the Tech Mod life cycle. Both implementation and performance of projects are incentivized (government funded) by the Tech Mod "business deal" included in contract F33657-81-C-0556. The savings from the Tech Mod program are being realized through reduced costs on the C-5 Wing Modification contract. The model used by SPO personnel was a cash flow model developed by the Lockheed Company.

GLAC Tech Mod Program Assumptions

The assumptions used in the GLAC Tech Mod program are as follows (15:Atch 8):

1. Assumption of the capital budgeting technique IRR apply - i.e. investment occurs at the start of each year savings are realized at the end.
2. Depreciation costs are completely recoverable.

3. Depreciation's effect on corporate income tax in accordance with IRS Tax Law 1981 not CAS 409.

4. Corporate tax rate of 46% was assumed.

5. Investment tax credit of 10% was assumed.

6. Overhead expenses such as depreciation (409), insurance property taxes, cost of money (414) are factored by a seven year matrix (.04, .16, .22, .21, .19, .16, .04)

7. A 20% performance incentive was assumed after successful installation of equipment.

<u>GLAC Tech Mod Program Variables</u>

The variables used in the GLAC Tech Mod program are listed below (15:Atch 8).

1. Initial investment made by the Lockheed Company.

2. Government investment in technology.

3. Contractor cost - an offset shown only on Lockheed cash flow analysis.

4. Profit/cost of money - the Cost Accounting Standards Board (CAS 414) allows a percent of the cost of investing in facility improvement to be used in contractor profit calculations.

5. Savings as a result of new technology.

6. Overhead expenses - depreciation, property taxes, insurance, and cost of money.

7. Income tax effect on overhead expenses.

8. Investment tax credit - 10% of initial investment.

9. Residual value of asset and income tax effect on either the gain or loss.

10. Other cash flows such as commercial savings and a planned 20% performance incentive.

By assigning appropriate values to the variables above, an after tax cash flow can be calculated for each

year. Care must be taken to ensure proper positive or negative values are recorded with respect to either government or contractor cash flow. After annual cash flows are determined, the GLAC model calculates appropriate IRR, NPV, and PBP values.

GLAC Tech Mod Program Implementation

Only the IRR capital budgeting technique was emphasized by the Airlift SPO not the NPV or PBP (15:Atch 8). By adjusting the performance incentive and government funding awarded to Lockheed, the Airlift SPO attained favorable IRRs for both parties. As in the F-16 SPO, IRR percentages were not directly negotiated. The IRR was sensitive to the timing of government funds especially in the first three years of the Tech Mod Program. The GLAC model can also account for multiple sharing of savings on the part of either party (i.e., shared government savings: Army, Navy, or Air Force projects; or shared Lockheed savings: commercial versus government projects).

B-1B Tech Mod Program Overview

Management responsibility for the B-1B Tech Mod program with Rockwell International in El Segundo, California is currently located within the B-1B System Program Office (SPO) at Aeronautical Systems Division (ASD), Wright-Patterson, AFB, Ohio. Personnel in the ASD Directorate of Contracting and Manufacturing (PM) assisted the B-1B SPO with the original economic analysis

prior to establishing the "business deal" with Rockwell (18:83). The internal rate of return (IRR) was the capital budgeting technique used by the SPO personnel to evaluate alternative capital investments.

Presently there are five Tech Mod projects approved/funded under the B-1B Tech Mod program with Rockwell International. Government funds (incentives) as well as resultant savings from each investment are distributed through the B-1B production contract. The B-1B Tech Mod program is in Phase II of the Tech Mod life cycle where new technologies are being developed and the implementation of capital equipment is tested.

The economic analysis model used by ASD/PM and B-1B SPO personnel closely approximates the ASD Tech Mod guide model, as the B-1B Tech Mod program is the most recent Tech Mod at ASD to establish a "business deal."

<u>B1-B Tech Mod Program Assumptions</u>

The assumptions made in the B-1B Tech Mod Program are as follows (18:83):

1. Assumptions of the capital budgeting technique IRR apply - i.e. investment occurs at the beginning of each year while savings are realized at the end of the year.

2. Depreciation costs are singled out for the B-1B program separately.

3. Depreciation effect on corporate income tax is in accordance with IRS guidelines.

4. A corporate tax rate of 46% was assumed.

5. The total initial investment was discounted back to year zero prior to IRR calculations.

B1-B Tech Mod Program Variables

The variables in the B-1B Tech Mod Program are listed below (18:83):

1. Initial investment made by Rockwell International.
2. Other investment by Rockwell - installation, checkout, etc.
3. Government investment - at price.
4. Savings estimated for investment - obtained from Rockwell International.
5. Contractor share of savings - at cost.
6. Government share of savings - at price.
7. Contractor depreciation in accordance with IRS guidelines - first subtracted out then added after taxes as it is a non-cash expense.
8. Investment tax credit - in accordance with IRS guidelines.

By assigning appropriate values to the variables above an after tax cash flow can be calculated for each year. Care must be taken to ensure proper signs (positive or negative) are used for to each variable. By use of a FORTRAN computer program (Appendix A), ASD/PM personnel then calculated an internal rate of return for each capital investment.

B1-B Tech Mod Program Implementation

By adjusting the levels of government funding various IRR percentages were achieved (18:83). Like the F-16 and Airlift SPO, actual IRR percentages were not

negotiated. All five Tech Mod projects required investment outlays over a 3-5 year period. In order to account more properly for the initial investment in the IRR calculation, the required investment was first discounted back to year zero then divided into the NPV of the annual cash flows. Neither the F-16 nor the Airlift SPO discounted the initial investment back to year zero.

Finally, ASD/PM personnel felt that variables such as imputed interest, profit or depreciation, and the residual value of equipment had little impact on the overall economic analysis of the potential Tech Mod project candidates.

ASD Tech Mod Economic Analysis Model Overview

Chapter V of the ASD Tech Mod Guide outlines specific procedures to be used in evaluating potential Tech Mod investments. All three capital budgeting techniques are explained and encouraged by the ASD model.

> Multiple figures of merit should be employed for each Tech Mod project. These include calculating net present values, internal rate of return, savings/investment ratio, and discounted payback period [1:47].

The ASD model is flexible with regard to assumptions and variables used. The ASD model also encourages broad interpretation with respect to benefits offered by the potential Tech Mod project.

No one contractual vehicle is mandated by the model to affect the "business deal" between government and

contractor. Application of the cost-benefit analysis should include all Air Force programs, DOD, and other government agencies as well as corporate entities affected by the capital investment.

ASD Tech Mod Economic Analysis Model Assumptions

The assumptions made by the ASD Tech Mod Economic Analysis Model are as follows (1:43):

1. The assumptions of three capital budgeting techniques apply - IRR, SIR, PBP.

2. All dollar figures are in then year dollars.

3. Operations savings, taxes, and depreciation cost data are obtained from the contractor.

4. A predetermined share ratio of savings is required to calculate both government and contractor savings figures.

5. The contractor will completely recover depreciation.

6. A corporate tax rate of 46% was assumed.

ASD Tech Mod Economic Analysis Model Variables

The variables included in the ASD Tech Mod Economic Analysis Model are listed below (1:44):

1. Initial investment made by contractor (Phase I, II, and III).

2. Other investment made by contractor - installation, checkout, etc.

3. Government investment - amount paid at price, may include Phase I & II effort if desired.

4. Other government investment - cost of money (CAS 414), allowability of depreciation in overheads (CAS 409), and award fees paid by the government to the contractor.

5. Savings - cost and price of estimated operations savings.

6. Contractor share of savings - depends on share ratio.

7. Government share of savings - depends on share ratio.

8. Award fee - any incentive paid directly to the contractor by the government.

9. Profit - any profit made by contractor during government investment (same as 3 above).

10. Profit on facilities - the Cost Accounting Standards Board allows a percent of the cost of investing in facility improvement to be used in contractor profit calculations.

11. Profit on depreciation - profit the contractor receives because depreciation is an allowable cost on government contracts.

12. Residual value - estimated value of capital investment at the end of a Tech Mod program.

13. Investment tax credit - in accordance with IRS guidelines; as a percent of initial investment.

By assigning appropriate values to the above variables, after tax annual cash flows can be obtained for the particular Tech Mod program. Care must be taken to ensure proper credit/debit values are assigned to each variable with respect to either government or contractor cash flow. After annual cash flows are obtained, the three capital budgeting techniques (IRR PBP, and SIR) can be calculated using the following formula of the ASD Tech Mod Guide (1:45).

$$\text{Present Value} = \text{Future Sum of Money} \times \frac{1}{\left(1 + \frac{\text{interest rate}}{\text{per period}}\right)^{\text{number of periods}}}$$

ASD Tech Mod Economic Analysis Model Implementation

The ASD model uses all three capital budgeting techniques to develop criteria for the decision maker(s) (1:44). Weighting of the various techniques as well as other qualitative criteria (social, technical, and political) remains the responsibility of the Tech Mod program manager and is not specifically dictated by the economic analysis model in Chapter V of the ASD Tech Mod Guide (1:6).

Literature Search

Profit 76

The early 1970s experienced a growing awareness of dwindling productivity growth within the defense industries. The trend of dwindling productivity growth was exacerbated by the rising costs of major weapon systems. Concerned with this trend, the DOD focused attention towards profit policy. Specifically, the DOD felt that weighted guidelines ignored contractor investment in developing a profit objective.

> In fact, there was concern that the policy, which was based heavily on estimated cost, may tend to discourage investment and reward high cost [22:1].

The former Deputy Secretary of Defense, Honorable William P. Clements, initiated a full-scale study of DOD profit policy.

> The goal was to develop policy revisions needed to motivate defense contractors to make investments which will reduce Defense Department acquisition cost [22:1].

The resultant bibliography of profit tax studies, reform hearings on capital formations, and Congressional criticisms and concerns yielded the following observations:

1. defense industry profit information is inadequate;
2. prior profit studies are unreliable and contradictory;
3. defense profits are being hidden;
4. meaningful competition is needed;
5. defense profits have been increasing;
6. government-furnished equipment results in unfair advantages;
7. contractor capital investment should be emphasized;
8. defense contractors are inefficient;
9. uniform accounting standards are needed;
10. Truth-in-Negotiations Act is ineffective; and
11. Renegotiation Act is ineffective.

Some specific recommendations were to:

1. shorten the period of capital cost recovery;
2. increase the Investment Tax Credit;
3. reduce capital gains taxation; and
4. eliminate the double taxation of corporate income by making dividends deductible.

As a result, to two major changes in calculating contractor profit were made.

> The first provides that the level of facilities investment will be recognized in the pre-negotiation profit objective where weighted guidelines are used. The second change provides that the imputed cost of

capital for facility investment (measured in accordance with Cost Accounting Standard 414) will be considered allowable on most negotiated DOD contracts which are priced on the basis of cost analysis [22:2].

Payoff 80

Despite the results of the Profit '76 Study, costs for defense weapon systems continued to grow at an alarming rate. Partially accountable for the increase in major systems acquisition cost was the ever declining productivity growth of the defense industry. "The fact of the matter is that defense contracting practices do not promote capital investment [12:25]." The contracting practices include:

> Annual buys that increase uncertainty and therefore, financial risks; the tendency of the Government to negotiate away savings that result from productivity investments on follow-on contract buys; contract awards based on criteria which do not recognize past investments or commitments to future investments; lack of price competition which dulls contractor sensitivity to cost reduction [12:26].

In response to declining productivity growth, General Alton D. Slay, former Commander Air Force Systems Command (AFSC), chartered the Have Payoff '80 Task Force to evaluate various methods to encourage contractor capital investment (12:i). The resultant study dated 1 Oct 80 provided the first formal publication of procedures and objectives of the Technology Modernization Program. Specifically, the study outlined the three phased joint venture approach to modernizing the contractor's facility. "An important part of the Payoff '80 charter was to make

Tech Mod a standard business practice for the Air Force [12:30]." In order to make Tech Mod a standard business practice within Air Force Systems Command (AFSC), Payoff '80 highlighted potential candidates for Tech Mod programs, established the corporate responsibility for coordinating Tech Mod programs (Deputy for Contracting and Manufacturing), and recommended the publication of a "How To" guide for Tech Mod. The final recommendation led to the Guide to Tech Mod and Contracting for Productivity published 28 July 1982 by Aeronautical Systems Division.

Producing More for Less

Major Eugene Kluter developed a "Guide for Writing Cost Reduction Contracts" at the Air Command and Staff College, which provided significant input to the ASD Tech Mod Guide economic analysis model (16:1). Kluter's work also served as an input to the Return on Investment model used in the Draft DOD Guide "Improving Productivity in Defense Contracting [7:82]."

The model used in Major Kluter's handbook was a Discounted Cash Flow (DCF) model which has Return on Investment (ROI) as an output. ROI is the major technique used to evaluate potential investments in the handbook. Variables used in the model include depreciation, lost profit on decreased cost, and imputed interest on capital investments.

Kluter's guide also proposes a benefits tracking system which is necessary to insure the success of any manufacturing cost reduction program (16:40). The tracking system makes use of established cost baselines while admitting the difficulty of tracking "real" reduced indirect costs. The five steps below are suggested:

1. Establish the baseline average standard hour value for the task center. Sampling techniques may be appropriate if there are large numbers of parts going into each task center.

2. Establish the new machine/process task description and apply the appropriate standard hours.

3. Develop learning curves for the baseline and the new machine/process.

4. Develop and project the Shipset No. 1 hours. the final output of step 4 is the delta man-hours that form the direct labor savings.

5. Apply appropriate labor rates to the direct labor hour savings.

Carlucci Initiatives

In his memorandum dated 30 April 1981, Mr. Frank Carlucci, the former Deputy Secretary of Defense, announced decisions/recommendations to improve the acquisition process (6:1). The recommendations address all aspects of the defense acquisition system including reduction of acquisition cost, shortening acquisition

time, improving weapons support and readiness, and improving the Defense Systems Acquisition Review Council (DSARC) process.

A specific Carlucci recommendation concerning the reduction of cost was to:

> Encourage capital investment to increase productivity in the defense industry by improved contracting, more reasonable risk sharing, and increased incentives [6:3].

Carlucci's initiative provided emphasis for programs such as Tech Mod from the DOD level. Visibility at the DOD level is the key to providing necessary government funding for the various Tech Mod program candidates.

Summary

The Technology Modernization Program has three distinct phases requiring specific management efforts. The economic analysis effort required in Phase II (the focus of this research project) employs fundamental capital budgeting techniques. Three existing Tech Mod programs studied used different assumptions, variables, and implementation guidelines than the assumptions, variables, and implementation guidelines dictated by the ASD model. In addition, significant consensus exists concerning declining productivity growth within the defense industry (12:31; 1:ii; 22:1; 16:3; 6:1; 33:5; 31:V-16). Study efforts within the DOD have recommended possible incentives to encourage capital investment by companies

within the defense industry. The recommended incentives range from modification of accounting standards and adjustment of tax laws to the development of specific programs within DOD such as Technology Modernization. The following chapter outlines the overall research methodology used in this research project.

CHAPTER III

Research Methodology

Introduction

This chapter outlines the specific methods used to evaluate the economic analysis model provided in Chapter V of the Aeronautical Systems Division (ASD) Tech Mod Guide. The research methodology was designed to answer the four research questions in Chapter I of this thesis. Figure 3-1 is a flowchart of the research methodology which assists in understanding the chapter.

Universe and Target Population

Air Force Systems Command (AFSC) is the statistical universe chosen for the research project. Aeronautical Systems Division (ASD), a buying division for AFSC, is the target population within the universe. The ASD Tech Mod Guide was published for use within the target population and it is within ASD that much of the Tech Mod expertise lies. The sample spaces chosen within the target population are identified below.

Sample Space for Research Question 1 and 4

A sample space of seven experts with experience in evaluating potential Tech Mod projects was selected from the target population (ASD). The small size of the sample space was due to the infancy of all Tech Mod applications within ASD and the limited number of experienced personel

with Tech Mod evaluation experience. A ranking of each variable in the ASD model was obtained from the "experts" using the attached interview guide (Appendix B). In addition, each expert provided an estimate for a good predictor of Internal Rate of Return (IRR) for a Tech Mod program. The mean responses for the "good predictor" estimates were used to establish the decision rule discussed below. Finally, each expert was asked for suggestions to improve the ASD model.

Sample Space for Research Question 2 and Research Question 3

As indicated in Chapter II of this thesis, several budgeting techniques are used to evaluate potential capital investments. Capital budgeting techniques are being used throughout Air Force Systems Command (AFSC) to evaluate investments designed to combat declining productivity growth. ASD published the Tech Mod Guide in July 1982 which employs the discounted payback period, internal rate of return, and savings investment ratio capital budgeting techniques. In order to evaluate the model in the ASD Tech Mod Guide, a sample space of one Tech Mod project within ASD was chosen. The Tech Mod project is managed by the F-16 System Program Office (SPO), a deputate within ASD. The sample space was chosen based on data accessibility of original estimates of investment savings and actual savings realized. The small size of the

sample space is due to the infancy of all Tech Mod projects within ASD. The Tech Mod project is known as the Capital Appropriation Request (CAR) 80 package.

Research Design

The following discussion outlines how the research questions were answered by comparing the original SPO estimates and the ASD model estimates to the actual savings realized for the CAR 80 Tech Mod project. The decision rule used to evaluate the original SPO estimate and the ASD model was obtained by polling experts on Technology Modernization with ASD. Finally, ASD Tech Mod experts rated each variable and suggested possible improvements to the ASD model in order to answer the fourth research question.

Figure 3-1 graphically describes the overall methodology employed. The estimates and actual rates of return and the decision rule allow comparisons which are depicted by rectangles which lead to conclusions depicted by triangles.

Data Collection

Data was collected and analyzed in order to answer each of the research questions.

Research Question #1. What is a good predictor of an actual rate of return for a particular Tech Mod project?

Seven experts with experience in evaluating potential Tech Mod projects at ASD were polled to answer the decision rule research question. The experts (see

Appendix C for individuals interviewed) were asked to establish a range for a good predictor of IRR. The range was expressed as a percent of the original estimate. Both the high and low responses were deleted. By taking the mean response of ranges between estimated and actual rates of return a decision rule was developed. The range (decision rule) was applied to the comparisons of the original SPO estimate and ASD model estimate to the actual rate of return, in order to answer the second and third research questions.

Research Question #2: Was the capital budgeting model used by the SPO to evaluate potential Tech Mod investments a good predictor of the actual rate of return experienced by implementing the investment?

The CAR 80 package was originally evaluated by F-16 SPO personnel using the Internal Rate of Return (IRR) capital budgeting technique. The original evaluation used the assumptions, variables, and implementation guidelines listed in Chapter II of this thesis. The product of the evaluation was a SPO estimate of the percent rate of return for the CAR package. The SPO estimate of the percent rate of return was compared to the actual rate of return as published by General Dynamics as of 7 May 1983. By using the decision rule discussed above, the comparison of SPO estimated rate of return versus actual rate of return was used to answer the second research question.

Research Question #3: Is the ASD model a better predictor of the actual rate of return experienced by implementing a Tech Mod project than the original SPO estimate?

The ASD model was applied to the CAR 80 Tech Mod project 'expost-facto' in order to develop an ASD model estimated rate of return. The ASD model was applied in accordance with the assumptions, variables, and implementation guidelines listed in Chapter II of this thesis. The product of the ASD model application was an estimate of the percent rate of return for the CAR 80 package. The ASD model estimate of the percent rate of return was compared to the actual rate of return as published by General Dynamics as of 7 May 1983. If the ASD model predicted a rate of return closer to the actual rate than the SPO estimate, the ASD model would have been considered a better predictor of rate of return, and the answer to the third research question would be in the affirmative. Conversely, if the ASD model predicted a rate of return further from the actual rate of return than the original SPO estimate, the ASD model would not be classified as a better predictor of rate of return and the answer to the third research question would have been negative.

Research Question #4: What variables in the ASD model have the greatest impact on rate of return and what improvements could be made to the ASD model?

The 13 variables in the ASD model develop annual cash flows (positive or negative) which then enable development of the capital budgeting techniques such as

IRR, SIR, and PBP. Changes to the variables in the ASD model would result in changes in the resulting capital budgeting techniques such as Internal Rate of Return. In order to more fully understand the impact the 13 variables have on IRR, seven experts with experience in evaluating potential Tech Mod projects at ASD were polled to answer the fourth research question. Each expert was asked to assess the 13 variables and the variable's impact on rate of return calculations. By taking the mean response for each variable, a rank ordering was developed for the variables in the ASD model. Two statistical tests (Friedman Two-way Analysis of Variance and the Kendall Coefficient of Concordance) were performed to ascertain agreement among the experts on the ranking of variables. The test results are in Appendix D. Additionally, suggestions to improve the ASD model were solicited from each expert and are presented with the rank ordering of the variables to answer the fourth research question.

Summary

Two sample spaces were obtained by selecting Aeronautical Systems Division (ASD) as the target population from the universe of Air Force Systems Command (AFSC). The first sample space consisted of seven experts in the field of Technology Modernization and the second sample space was the CAR 80 Tech Mod Project managed by the F-16 System Program Office. Once a decision rule was

established, comparisons were made in order to answer the research questions following the methodology depicted by Figure 3-1. The next chapter analyzes the data collected by the researcher.

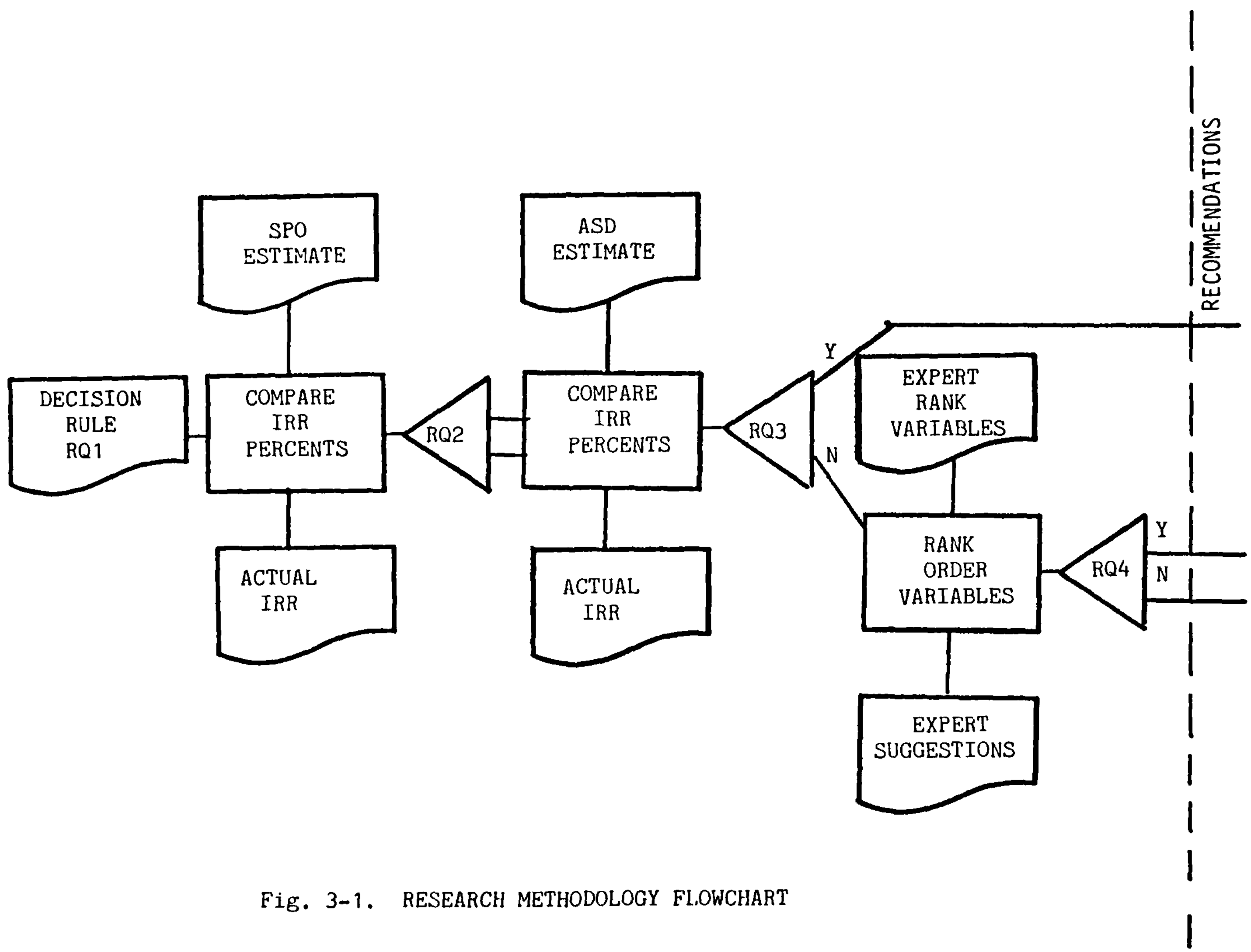

Fig. 3-1. RESEARCH METHODOLOGY FLOWCHART

CHAPTER IV

DATA ANALYSIS AND FINDINGS

Introduction

This chapter presents the data collected and analyzes the research results in accordance with the methodology prescribed in the previous chapter. The data are presented in the order of the four research questions.

Research Question #1

Seven experts with experience in evaluating potential Tech Mod programs were asked the first research question which called for a range for a good predictor of rate of return. The interview guide (see Appendix B) expressed the range as a percent of the original estimate. Table 4-1 illustrates the mean response obtained from the "experts" used for the decision rule.

TABLE 4-1

DECISION RULE

Expert*	Allowable range for a good predictor (as a % of original estimate)
1	5
2	10
3	10
4	25
5	5
	$\Sigma x =$ 55

Mean range for a good predictor = x/n = 55/5 = 11

*The high and low extreme responses were not used to develop the mean range for a good predictor.

The decision rule used to answer the second and third research questions defined a good predictor for Internal Rate of Return (IRR) as that model which estimates an IRR within 11% of the actual IRR. To clarify, assume model A estimated an IRR of 25%. Using the above decision rule, the allowable range for model A to be a good predictor would have been 11% of 25% or $\pm$ 2.75%. Therefore, if the actual rate of return was between 22.25% and 27.75% model A was a good predictor using the 11% decision rule.

The 11% decision rule was used to establish a 'good predictor' range for both the SPO estimate and ASD model estimate for IRR.

Research Question #2

To answer the second research question, two internal rate of return (IRR) calculations were necessary; (1) the SPO estimate of IRR, and (2) the actual IRR. The 11% decision rule was applied to the SPO estimate to achieve a range for the actual IRR.

F-16 SPO personnel originally calculated an IRR of 24% for the CAR 80 Tech Mod program (9:13). As defined in Chapter II of this thesis, IRR is the discount rate which when applied to a stream of cash flows drives the net present value as close to zero as possible. The variables used in calculating the 24% IRR were also explained in Chapter II.

Applying the 11% decision rule to the 24% IRR estimated by the SPO for the CAR 80 Tech Mod Program yields a "good predictor" range of ± 2.64%. If the actual IRR fell between 21.36 and 26.64 percent the answer to the second research question would have been "yes."

For the CAR 80 Tech Mod Program, General Dynamics had the potential to earn 11% (2.5M) of the total program savings which were estimated at 22.7M dollars (10:i). As of 7 May 1983, General Dynamics reported a total savings 31% less than the original F-16 SPO estimate. Unless future cash flows increase at a rapid rate, the actual savings would possibly remain 31% less than the original estimate. The reduction in savings directly causes a reduction in net cash flows for the affected years. By reducing net cash flows, the discount factor (IRR) must also be reduced to keep the sum of the discounted cash flows (net present value, NPV) as close to zero as possible. Table 4-2 illustrates the original SPO estimate of 24% for the IRR. The anticipated share of program savings (2.5M) for General Dynamics is the second variable (see page 23 of this thesis for a discussion of all the variables included in the original F-16 SPO Model) used to develop a Net Cash Flow for each year in Table 4-2. The 24% discount factors were then applied to each year in the Net Cash Flow column to achieve a Discounted Cash Flow. The discount rate which yields a Discounted Cash Flow sum

close to zero (for Table 4-2, 24%) is defined as the original F-16 SPO estimate of IRR.

TABLE 4-2 (9:13)

SPO ESTIMATE OF IRR FOR CAR 80
($ in 000's)

YEAR	NET CASH FLOW*	24% DISCOUNT FACTOR	DISCOUNTED CASH FLOW*
80	(1426)	.806	(1149)
81	(3874)	.650	(2518)
82	1547	.524	811
83	3864	.423	1558
84	1966	.341	670
85	1245	.275	342
86	795	.222	176
87	388	.179	69
88	11	.144	2
89	(54)	.116	(6)
		Net Present Value	(45)

*A net cash flow and discounted cash flow in parentheses indicates a negative cash flow to General Dynamics.

Table 4-3 calculates the actual Internal Rate of Return for the CAR 80 Tech Mod Program. Because General Dynamics reported a total savings 31% less than the original estimate, Net Cash Flow figures for 1982 and 1983 were adjusted downward from the original F-16 SPO estimate of IRR (Table 4-2). In order to achieve a net

present value close to zero (39), 12% discount factors were applied to the Net Cash Flows derived from the variables used by the F-16 SPO (see page 23 of this thesis). Therefore, the actual IRR for CAR 80 Tech Mod Program is 12%.

The difference between SPO estimated IRR (24%) and actual IRR (12%) fell outside the 11% good predictor

TABLE 4-3 (9:13)

ACTUAL IRR FOR CAR 80
($ in 000's)

YEAR	NET CASH FLOW*	12% DISCOUNT FACTOR	DISCOUNTED CASH FLOW*
80	(1426)	.8929	(1273)
81	(3874)	.7972	(3088)
82	1210	.7118	861
83	2029	.6355	1290
84	1966	.5674	1115
85	1245	.5066	630
86	795	.4523	360
87	388	.4039	157
88	11	.3606	4
89	(54)	.3220	(17)
		Net Present Value	39

*A net cash flow and discounted cash flow in parenthesis indicates a negative cash flow to General Dynamics.

range. Because the actual IRR was outside the range, using the decision rule, the second research question was answered negatively.

Research Question #3

To answer the third research question two Internal Rate of Return (IRR) calculations were necessary: (1) the ASD model estimate of IRR, and (2) the actual IRR. The 11% decison rule was applied to the ASD estimate to achieve a range for the actual IRR.

The ASD model was applied expost-facto to the CAR 80 Tech Mod program to derive an IRR. Initial data were assumed accurate and were applied in accordance with ASD model guidelines outlined in the literature review of this thesis. To determine annual cash flows the thirteen ASD model variables were used where appropriate. Two additional variables included in the original F-16 SPO economic analysis were not used for the ASD model estimate of IRR. The two additional variables were lost profit and the European Participating Government (EPG) share of investment costs. A discussion of the variables used in the F-16 SPO economic analysis was included in the author's literature review.

Table 4-4 summarizes the variables included in the ASD model and in the F-16 SPO model used to calculate IRR for the CAR 80 Tech Mod Program. The difference between the two models is in variables 14 and 15 (Lost Profit and

EPG). The variables used in the ASD model were added together to achieve annual cash flows which are listed under 'Adjusted Net Cash Flows' in Table 4-5. The Adjusted Net Cash Flows were then discounted by a 28%

TABLE 4-4

MODEL DIFFERENCES IN DETERMINING CASH FLOWS

Included in the ASD Model		Variables	Included in the F-16 SPO Model
YES	1.	Initial contractor investment	YES
NO	2.	Other contractor investment	NO
NO	3.	Government investment	NO
YES	4.	Other government investment (Cost of Money at 14.63%)	YES
YES	5.	Savings ($22.7M for total F-16 program)	YES
YES	6.	Contractor Share (11%)	YES
YES	7.	Government Share (89%)	YES
YES	8.	Award fee ($2.3M)	YES
NO	9.	Profit on government investment	NO
NO	10.	Profit on facilities (CAS 414)	NO
YES	11.	Profit on depreciation (13%)	YES
NO	12.	Residual value	NO
YES	13.	Investment tax credit (10%)	YES
NO	14.	Lost profit on reduced costs (10%)	YES
NO	15.	European participating government share of investment	YES

TABLE 4-5

ASD MODEL ESTIMATE OF IRR (28%)

	Remove Lost Profit & EPG Variables	After Tax Adjustment	Adjusted Net Cash Flows	28% Discount Factor	Discounted Cash Flows*
1.	---	---	(1426)	.7813	(1114)
2.	54	29	(3845)	.6104	(2347)
3.	151	82	1629	.4768	777
4.	160	87	3951	.3725	1472
5.	214	116	2082	.2910	606
6.	382	206	1451	.2274	330
7.	445	240	1035	.1776	184
8.	479	259	647	.1388	90
9.	503	272	283	.1084	30
10.	198	107	53	.0847	4
				Net Present Value	32

*An adjusted net cash flow and a discounted cash flow in parentheses indicates a negative cash flow to General Dynamics.

discount factor (which equates to an IRR) to achieve a net present value close to zero. Therefore, the ASD model yielded an IRR for CAR 80 of 28%.

Table 4-3 (page 52) illustrated an actual IRR for CAR 80 of 12%. Because 12% fell outside the good predictor range for the ASD model (between 25% and 31%) the author concluded that the ASD model was not a good predictor of IRR for the F-16 Tech Mod Program. In addition, the ASD model provided a "poorer estimate" of the actual IRR than the F-16 SPO model. Therefore, the ASD model was not a better predictor of IRR for CAR 80 than the F-16 SPO model and the answer to the third research question was answered as "no."

Research Question #4

To answer the fourth research question, seven experts with experience in evaluating potential Tech Mod projects were asked to rate each variable in the ASD model according to the potential impact on the resulting rate of return. Appendix B is the interview guide used by the researcher. Additionally, suggestions were sought from the experts on ways to improve the ASD model.

Variables Rated

Table 4-6 illustrates how each expert rated the variables in the ASD model and provides a mean response for each variable. Table 4-7 uses the mean response for each of the 13 variables and ranks the variables from

strongest to weakest impact on IRR. Appendix D provides two variance analysis statistical tests used to confirm the agreement among the experts for the results presented in Table 4-7.

TABLE 4-6

EXPERT OPINION OF 13 VARIABLES IN ASD MODEL

(1 = Weakest, 2 = Strongest impact on IRR)

Variables	Experts							Mean Response* #
	1	2	3	4	5	6	7	
1	7	7	2	7	7	7	7	6.3
2	7	7	2	4	3.5	4	5	4.6
3	7	7	2	5	7	7	7	6
4	4	7	1	5	3	1	5	3.7
5	4	1	7	7	7	7	7	5.7
6	4	7	6	7	7	6	5	6
7	3	7	6	4	7	6	5	5.4
8	6	3	6	5	5.5	3	6	4.9
9	3	7	1	5	2	3	5	3.7
10	3	1	1	4	2	1	6	2.6
11	3	7	6	5	2	4	6	4.7
12	4	3	5	1	2	5	3	3.3
13	7	7	5	7	3	4	6	5.6

*The two statistical tests performed in Appendix D support the author's use of the mean response number to rank order the variables in Table 4-7.

As expected, the investments made by both government and contractor along with the savings provided by the investment were considered by the experts to have the greatest impact on the ASD model's calculations of IRR.

TABLE 4-7

IMPACT OF ASD MODEL VARIABLES ON IRR*

Strongest	Initial investment by contractor (1)
	Government investment (3) & contractor share of savings (6)
	Total Program Savings (5)
	Investment tax credit (13)
	Government share of savings (7)
	Award fee/incentive paid to contractor (8)
	Profit on depreciation (11)
	Other investment made by contractor (2)
	Other government investment (4) & profit made during government investment (9)
	Residual value (12)
	Profit on facilities (10)
Weakest	

*The numbers in the parentheses correspond to the original listing for the variables provided in the literature review.

However, the importance of the investment tax credit was weighted above the variable of the government share of

savings. The concern about other qualitative benefits from Tech Mod programs (such as political and social factors) could explain the fact that investment tax credit was ranked above the government's share of savings.

Four of the five lower ranked variables are regulated by the Cost Accounting Standards Board. The lower ranked variables are the subject of many DOD studies (See Chapter II of this thesis) and are designed to provide incentives to the contractor to invest in capital equipment. However, from the ranking provided in Table 4-7 one might question the focus of the DOD studies on accounting standards and various tax laws.

Suggestions for Improving ASD model

Using the interview guide (Appendix B) the researcher received the following suggestions to improve the ASD model.

1. The most often cited area for improving the ASD model was to make the savings estimate (variable #5) more accurate. The savings estimated were called "paper" savings by many experts due to the lack of traceability of Tech Mod savings after implementation. Without accurate post-assessments (Phase III realized savings) refinement of the ASD model would be difficult.

The experts agreed that programmatic changes (such as economic, schedule, quantity and labor rate changes) caused the major difference between estimated and actual

savings. Economic changes included shifts in the inflation rates used to project outyear savings dollars. For example, one estimate of inflation for the Low Altitude Navigation Infrared for Night (LANTIRN) Tech Mod program managed by ASD was a 9.5 percent inflation rate (constant to 1989) while the current inflation rate estimate is between 3-5 percent (17:20). Schedule changes within ASD are not uncommon and also blamed for causing the differences between estimated and actual savings. The F-16 Tech Mod savings have been affected by changing the schedule for the 1388 total aircraft. The schedule change in the F-16 Tech Mod Program resulted in a rate change from 18 aircraft/month to 15 aircraft/ month (9:83). Reduced rates for productivity improving investments equated to reduced actual savings for the capital investment. Finally, labor rate changes caused less savings for the F-16 Tech Mod investments. According to the F-16 Tech Mod program manager, the labor rate reduction was the direct result of the improved productivity caused by the Tech Mod Program (9:83).

2. Chapter II of this thesis pointed out that the payback period capital budgeting technique was inferior to other capital budgeting techniques (SIR and IRR), because payback period did not take into account the time value of money. Despite the theoretical drawback of the payback period it remains in use throughout industry. Because of

its use by aerospace managers, some experts felt the PBP should be used instead of the IRR to evaluate potential Tech Mod programs.

3. The timing of cash flows was assumed by all three programs (GLAC, F-16, and B-1B) and the ASD model according to the IRR capital budgeting technique. Specifically, investment outlays were assumed to occur at the beginning of each year while savings were assumed to be realized at the end of each year. In the case of GLAC a sensitivity analysis conducted by Airlift SPO contracting personnel revealed a change of 10% in total program IRR with just a six month shift in the purchase of capital equipment. The timing of equipment purchase and operational installment was felt to be critical and was incorporated into two of the Tech Mod contracts.

4. "Lost profit" is not included in the ASD model and was primarily responsible for causing the difference between estimated and actual IRR as demonstrated in answering Research Question 3. "Lost profit" is defined as the profit which a contractor loses due to reduced contract costs, since profit is normally calculated as a percent of cost on DOD contracts. One expert felt that to ignore lost profit was a serious error and failed to consider the contractor's basic motivation: profit. Lost profit's deletion from the ASD model contributed to higher IRR.

5. Two experts felt that the focus on Tech Mod programs often centered around major weapon system acquisitions rather than specific technologies needing modernized. The example cited was the LANTIRN Tech Mod program dealing with the electronics industry. According to one expert, the electronics industry does not require Tech Mod programs as much as the aerospace industry. The expert felt that tying the Tech Mod program to specific technologies, as opposed to major weapon system acquisitions, would result in greater competition and more efficient use of the Tech Mod funds.

The above observations from experts suggest possible improvements to the ASD model. In addition, users of the ASD model would benefit greatly from the insight into the weighing of the variables and how savings estimates could change.

Summary

This chapter answered the four research questions with data provided by the F-16 SPO and interviews of "experts" in the field of Technology Modernization. The researcher found that the original F-16 SPO estimate of Internal Rate of Return (IRR) was not a good predictor of the actual IRR. Furthermore, the ASD model was not a better predictor of IRR than the F-16 SPO estimate. Finally, the variables in the ASD model were ranked by "experts" according to the impact on developing IRR, and

the experts offered suggestions for improving the ASD model. Chapter V lists conclusions of the author's research project and makes recommendations for improving the ASD model. The author then suggests areas for future research.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

Introduction

This chapter addresses several conclusions about the evaluation of the ASD Model. The conclusions were based on the responses to the research questions and other comments from the Tech Mod "experts." Recommendations based on the conclusions are then offered by the researcher. Through the many formal and informal interviews conducted in the author's research project, further areas for research were identified.

Summary of Research Methodology

Two sample spaces from the target population (Aeronautical Systems Division) provided data necessary to answer the research questions in Chapter I of this thesis. The research questions compared the ASD Model to the F-16 SPO Model and looked for potential improvements to the ASD Model. A decision rule was established to compare the ASD and F-16 Models while "expert" rankings and suggestions provided potential improvements for the ASD Model. Figure 3-1 graphically portrays the research methodology employed.

Conclusions

The original estimate of IRR accomplished by F-16 SPO personnel was much higher than that IRR actually

experienced on the F-16 Tech Mod Program. Cited as the primary cause for the high estimate were programmatic changes (i.e., economic, schedule, etc.) which caused the original estimate of operational savings to be inflated.

The ASD model was applied expost-facto by the researcher to estimate an IRR for the F-16 Tech Mod Program (CAR 80). The estimate of IRR resulting from the ASD model was much higher than that IRR actually experienced. In fact, the ASD model predicted an IRR even further from the actual IRR than the model originally used by F-16 SPO personnel. The primary reason for the different estimates was the exclusion of the "lost profit" variable by the ASD model.

The ranking of the variables included in the ASD model according to the impact on IRR illustrated greater concern about the investment and savings data than that data dictated by Cost Accounting Standards. Specific suggestions provided expert consensus on the importance of the savings estimates in calculating IRR. The emphasis on the savings estimates variable can not be understated. The actual rate of return experienced by the CAR 80 Tech Mod Program was significantly lower than that IRR predicted by the F-16 SPO. The primary reason for the inaccurate rate of return (IRR) estimate was the inaccurate savings estimate. The savings estimate variable was the single most important variable in the ASD

model. This research result was verified by comparing the empirical results for the most mature Tech Mod Program at ASD (CAR 80) and by the expert rankings and interviews.

Implications of Research

The implications of this research project are aimed at two groups: Technology Modernization Program policy makers and Tech Mod Program practitioners. The policy makers should include "Lost Profit" as a variable in the ASD Model to make the ASD Model a more accurate predictor of Internal Rate of Return. Also, policy makers should encourage better traceability of Tech Mod Programs savings in order for future research efforts such as this to further verify the ASD Model.

This research project provides numerous implications for the Tech Mod practitioner. First, the practitioner should realize the pivotal importance of the savings estimates used in the ASD Model. In addition, the timing of savings estimates can and does effect IRR calculations significantly. Finally, the background and models used by two other Tech Mod Programs (GLAC and B-1B) summarized in the literature review of this thesis provide the practitioner with a greater understanding of the ASD model.

Recommendations

The author's specific recommendations for implementation are listed below:

1. Extreme care should be taken to assure accurate savings estimates are obtained prior to application of the ASD model. Inflation, schedule, quantity, and labor rate estimates should be the most current information available. Additionally, potential changes in the above estimates should be addressed with respect to the impact on rate of return calculations (i.e., IRR). Management can then make informed decisions and plan for inevitable changes. Finally, the ASD model should be applied whenever programmatic changes impact existing Tech Mod programs and rates of return.

2. "Lost profit" should be included as a variable in the ASD model. The exclusion of "lost profit" in the ASD model resulted in a 4 percent shift for IRR in the ASD model, comparing 28% in Table 4-5 to 24% IRR in Table 4-2. Ignoring lost profit ignores the contractor's motivation and is unrealistic as well as detrimental to evaluating potential Tech Mod investments.

3. The payback period (PBP) capital budgeting technique should be calculated to evaluate potential Tech Mod projects. The ASD model encourages the calculation of PBP. The programs studied and experts interviewed did not calculate a PBP and in so doing ignored a major tool used in industry and available in the ASD model.

4. The timing of cash flows is so critical to calculating IRR that periods shorter than one year should

be used. Assuming outlays occur at the beginning of each year and savings occur at the end is often not the case. Not planning (and calculating) for schedule changes within ASD ignores the inevitable.

5. Finally, the traceability of Tech Mod savings achieved should be encouraged to provide more actual rates of return on future programs. This would enable future research efforts and possible refinement of savings estimating techniques.

Areas for Further Research

The ranking of the variables used in the ASD model in Table 4-7 suggested several areas for future research. Assuming the initial investments are known with certainty (as they most often are), the savings estimate is the first variable that needs refinement. A future research project should determine exactly how the savings estimates are developed (i.e., fact finding, history, parametric, etc.).

The author's research project should be replicated by applying the ASD model to other Tech Mod programs as actual savings data becomes available.

Concluding Thoughts

Reviewing the literature and interviewing several "experts" at Aeronautical Systems Division leads the author to approach with caution the published merits

of any Technology Modernization Program. Fluctuating government funding and diluted management within DOD (studied while attending the Air Force Institute of Technology) serve to restrict long term capital equipment investment within the defense industrial base. Investment programs such as Tech Mod should, therefore, be viewed not as a solution but a (and not necessarily the only) step towards improving the defense industry.

APPENDICES

APPENDIX A

FORTRAN PROGRAM FOR CALCULATING IRR

FORTRAN PROGRAM FOR CALCULATING IRR

```
TYPE ROIF FORTRAN

@PROCESS FREE SC($CTS)
"

DIMENSION TAB(24:30,15)
"

CHARACTER*8 FN
"

REAL*8 RBOTT,RTOP,R1,S1,TAB,X1

     PRINT*,'ENTER NUMBER OF YEARS  0-14'
     READ(5,FMT=*) IYR
     PRINT*,'ENTER FILENAME FOR DATA FILE'
         READ(5,FMT='(AB)') FN
"
"*************************************************************************
 CALL $CTS(IERR,'FILEDEF ','10      ','DISK    ',FN,'FILE         ',-
                   '(LRECL  ','132     ','BL      ','132     ',-
                   'RECFM   ','FB      ')
"*************************************************************************
"
READ(10,FMT=*)  (TAB(24,J),J=1,IYR)
READ(10,FMT=*)  (TAB(29,J),J-1,IYR)
"
     IR=24
4520 RI=0
     CALL NPV(TAB,R1,S1,IR,IYR)
     X1 = TAB(IR,1)-S1
     IF(X1) 4551,4721,4560
4551 R1 = 3.2
     X1 = 0
"
4557 IF(X1.LT.0) GOTO 444
       RTOP = R1
       R1 = R1/2
       CALL NPV(TAB,R1,S1,IR,IYR)
       X1=TAB(IR,1)-S1
     GOTO 4557
    4444 CONTINUE
"
     RBOTT = R1
     GOTO 4571
4560 R1 = -1.2
     X1 = 0
"
```

```
4566 IF(X1.GT.0) GOTO 4568
       RBOTT = R1
       R1 = R1/2
       CALL NPV(TAB,R1,S1,IR,IYR)
       X1=TAB(IR,1)-S1
           GOTO 4566
     4568 CONTINUE
"
     RTOP = R1

     IF(RTOP.LT.-1.0.OR.RTOP.EQ.-1.0)THEN
      PRINT*,'IRR IS LESS THAN OR EQUAL TO -100% AND IS THEREFORE ','
              'MEANINGLESS'
      GOTO 9000
     ENDIF
"
4571 R1 = (RTOP+RBOTT)/2
     CALL NPV(TAB,R1,S1,IR,IYR)
     X1 = TAB(IR,1)-S1
     IF(X1.LT..001.AND.X1.GT.-.001) GOTO 4721
     IF(X1.LT.0) RBOTT = R1
     IF(X1.GT.0) RTOP = R1
"
     IF(RTOP.LT-1.0.OR.RTOP.EQ-1.0) THEN
      PRINT*,'IRR IS LESS THAN OR EQUAL TO -100% AND IS THEREFORE ',-
              'MEANINGLESS'
      GOTO 9000
     ENDIF
"
     GOTO 4571
4721 R1 = R1*100

     IF(IR.EQ.24) THEN
       PRINT 4726,41
4726 FORMAT('0','  CONTRACTOR IRR - ',F8.3)
     ENDIF
"
     IF(IR.NE.24) THEN
       PRINT 4736,R1
4736 FORMAT('0','  GOVERNMENT IRR = ',F8.3)
     ENDIF
"
     IF(IR.NE.29) THEN
       IR = 29
       GOTO 4520
     ENDIF
"
9000 CONTINUE
     STOP
     END
@PROCESS FREE
```

```
"*************************************************************************
      SUBROUTINE NPV(TAB,R1,S1,IR,IYR)
"
      DIMENSION TAB(24:30,15)
"
      REAL*8 41,S1,TAB
"
         S1 = 0
         DO 9850 I = 1,8YR-1
            S1 = S1+(TAB(IR,I+1)/(1.+R1)**I)
9850 CONTINUE
     RETURN
     END

R;

C>
```

APPENDIX B

INTERVIEW GUIDE

INTERVIEW GUIDE

Please rate each variable on it's impact on the Internal Rate of Return (IRR) calculation with 1 being the weakest and 7 being the strongest.

	Weakest						Strongest
1. Initial investment made by contractor (phase I, II, and III)	1	2	3	4	5	6	7
2. Other investment made by contractor - installation, checkout, etc. (capitalize cost)	1	2	3	4	5	6	7
3. Government investment - amount paid at price, may include phase I and II effort if desired.	1	2	3	4	5	6	7
4. Other government investment - cost of money (CAS 414), allowability of depreciation in overheads (CAS 409), and award fees paid by the government to the contractor.	1	2	3	4	5	6	7
5. Savings - cost and price of estimated operations savings.	1	2	3	4	5	6	7
6. Contractor share of savings - depends on share ratio.	1	2	3	4	5	6	7
7. Government share of savings - depends on share ratio.	1	2	3	4	5	6	7
8. Award fee - any incentive paid directly to the contractor by the government.	1	2	3	4	5	6	7
9. Profit - any profit made by contractor during government investment in variable #3 above.	1	2	3	4	5	6	7

		Weakest						Strongest
10.	Profit on Facilities - the Cost Accounting Standards Board allows a percent of the cost of investing in facility improvement to be used in contractor profit calculations.	1	2	3	4	5	6	7
11.	Profit on depreciation - profit the contractor receives because depreciation is an allowable cost on government contracts.	1	2	3	4	5	6	7
12.	Residual value - estimated value of capital investment at the end of a Tech Mod program.	1	2	3	4	5	6	7
13.	Investment tax credit - in accordance with IRS guidelines; as a percent of initial investment.	1	2	3	4	5	6	7

A good predictor of the Internal Rate of Return would yield an estimate within

0 5 10 15 _____

percent of that experienced.

APPENDIX C

EXPERTS INTERVIEWED AT ASD

EXPERTS INTERVIEWED AT ASD

(25-29 July 1983)

1. Mr. F. Donnely, Pricing Analyst for the Contracting/ Manufacturing Directorate, responsible for verifying economic analyses performed at ASD.

2. Maj T. Fitzgerald, Tech Mod Program Manager, responsible for all aspects of the Tech Mod Program in the F-16 System Program Office.

3. Mr. I. Guterman, Management Analyst, who did the economic analysis for the Lockheed-Georgia Company Tech Mod Program.

4. Captain J. Wayne, Tech Mod Contracting Officer, who assisted in negotiations and the economic analysis performed for the B-1B System Program Office.

5. Mr. L. Krisp, Tech Mod Contracting Officer, who did the economic analysis and negotiated the Tech Mod Program for the LANTIRN System Program Office.

6. Captain D. Odor, responsible for coordinating, planning, and budgeting all Tech Mod Programs in AFSC, working in the Aerospace Industrial Modernization Office.

7. Captain G. Varney, Quality Assurance Division, Contracting/ Manufacturing Directorate, who assists in reviewing the economic analyses and negotiations for Tech Mod programs within ASD.

APPENDIX D

VARIANCE ANALYSIS ON EXPERT RANKINGS

VARIANCE ANALYSIS ON EXPERT RANKINGS

Introduction

Two statistical tests were performed to support the variable ranking in Table 4-7. The Friedman Two-Way Analysis of Variance examines the overall difference among the 13 variables as the seven experts ranked them. Specifically, the Friedman Test evaluated the hypothesis that no significant difference exists among the 13 variables as ranked by the experts (H_O). The Kendall Coefficient of Concordance was calculated to examine how the experts ranked the variables with respect to the other experts. Specifically, the Kendall Coefficient tested the null hypothesis that the rankings of the experts were unrelated (H_O). Table D-1 provides the data necessary to apply the test statistics taken from Dr. S. Siegel's book titled, Nonparametric Statistics for the Behavioral Sciences (30:5). Table D-1 converts the rating for each variable by the experts provided in Table 4-6 to a single ranking for all the variables in the ASD model.

TABLE D-1

EXPERT RANKING OF VARIABLES IN ASD MODEL

Variables (N = 13)	Experts (k = 7)							R_j	$\left(R_j - \frac{\Sigma R_j}{N}\right)^2$
1	2.5	2	4.5	2	9	2	2.5	24.5	506
2	2.5	8	4.5	9.5	9	11	7	51.5	20
3	2.5	2	4.5	2	9	6.5	2.5	29	324
4	7	12.5	4.5	9.5	12	6.5	8.5	60.5	182
5	7	2	12.5	2	1	2	2.5	29	324
6	7	4.5	4.5	9.5	3.5	2	2.5	32.5	210
7	9	4.5	4.5	9.5	3.5	11	2.5	43.5	12
8	5	11.5	10.5	5.5	3.5	6.5	6	48.5	2
9	9	11.5	4.5	9.5	12	6.5	11.5	64.5	306
10	9	12.5	12.5	5.5	12	11	11.5	74	729
11	9	8	4.5	5.5	3.5	6.5	11.5	48.5	2
12	7	6	10.5	13	6.5	13	11.5	67.5	400
13	2.5	8	4.5	5.5	6.5	2	8.5	42.5	20
								616	3037

Friedman Two-Way Analysis of Variance

i. Null Hypothesis: H_O: The variables have no differential effect on IRR. H_A: the variables do have a differential effect on IRR.

ii. Significance Level. Let $\alpha = .05$ with N = 13 = the number of variables each expert ranked.

iii. Sampling Distribution. The Chi Square distribution is a good approximator of the Friedman test when N and/or k is large.

iv. Rejection Region. The region of rejection consists of all values of X^2 which are so large that the probability associated with their occurrence under H_0 is equal to or less than $\alpha = .05$.

v. Decision. Using the formula in Siegel's text (30:168) a computed value of X^2 results.

$$X^2 = \frac{12}{Nk(k+1)} \sum_{j=1}^{k} (R_j)^2 - 3N(k+1)$$

where $k = 7$ and $N = 13$ and R_j from Table D-1

$$X^2 = .01648\ (32246) - 312 = 219$$

With degrees of freedom equal to k-1 (6) and an alpha of .05, the critical value of the Chi Square is much greater than 12.59 and the probability of occurrence much less than .05; the null hypothesis is rejected and conclude there is significant difference among the variables as ranked by the experts. In other words, there was agreement among the experts in the ranking of the thirteen variables.

<u>Kendall Coefficient of Concordance</u>

i. Null Hypothesis. H_0: The expert rankings of the variables are unrelated to other expert rankings.

ii. Significance Level. Let $\alpha = .05$ with $N = 13$ = the number of variables each expert ranked.

iii. Sampling Distribution. The Chi Square is a good approximator of the Kendall Coefficient when N and/or K is large.

iv. Rejection Region. The region of rejection consists of all values of X^2 which are so large that the probability associated with their occurrence under Ho is equal to or less than $\alpha = .05$.

v. Decision. Using the formula given in Siegel's text (30:236) a computed value of X^2 results.

$$X^2 = \frac{S}{\frac{1}{12} KN(N+1)}$$

where S = 3037 from Table D-1, k = 7 and N = 13

$$X^2 = 28.6$$

With degrees of freedom equal to N-1 (12) and an alpha of .05, the critical value of the Chi Square distirbution is 21.03. Because the computed value of Chi Square is greater than 21.03 and the probability of occurrence less than .05, we reject the null hypothesis and conclude the expert rankings are related to one another. Rejection of the null hypothesis implies there was agreement among the experts as to the ranking of the 13 variables. The pooled ordering can serve as a standard to rank the variables in the ASD model. Table D-2 uses the R_j to develop a pooled ordering. The similiarity between Table D-2 and Table 4-7 served to statistically reinforce the use of the mean rating to develop Table 4-7.

AD-A135 635 ECONOMIC ANALYSIS MODEL EVALUATION FOR TECHNOLOGY MODERNIZATION PROGRAMS(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYSTEMS AND LOGISTICS 2/2

UNCLASSIFIED R E HAILS SEP 83 AFIT-LSSR-92-83 F/G 5/1 NL

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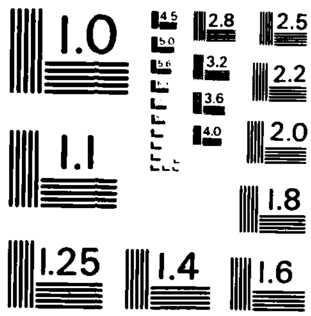

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

TABLE D-2

R_i to RANK*

Strongest	Initial investment by contractor (1)
	Government Investment (3) and savings (5)
	Contractor share of savings (6)
	Investment tax credit (13)
	Government share of savings (7)
	Award fee/incentive paid to contractor (8) and profit on depreciation (11)
	Other investment made by contractor (2)
	Other government investment (4)
	Profit made from government investment (9)
	Residual value (12)
Weakest	Profit on facilities (10)

*The numbers in the parentheses correspond to the original listing for the variables provided in the literature review.

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